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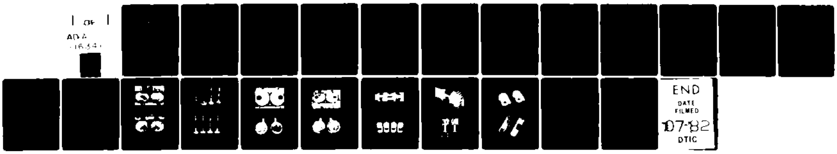

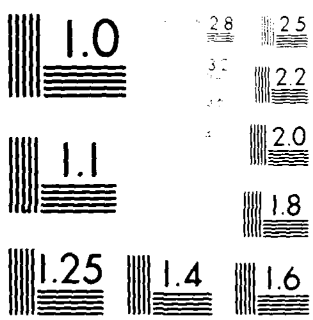
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ENGINEERING DEVELOPMENT ESTABLISHMENT

TECHNICAL NOTE

EXAMINATION OF LPG AND PETROL FUELLED FORD ENGINES

BY

N. WEBB

PUBLICATION EDE 3/82

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ENGINEERING DEVELOPMENT ESTABLISHMENT

EXAMINATION OF LPG AND PETROL FUELLED FORD ENGINES

SUMMARY

This Technical Note covers the examination and comparison of the condition of Ford 4.1 ℓ XB engines operated for approximately 100 000 km on liquified petroleum gas (LPG) and petrol.

The LPG engines exhibited less wear and were much cleaner than the petrol engines. However, the LPG exhaust valve faces were badly pitted and combustion chamber carbon build up was excessive.

Maribyrnong
April 1982

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TECHNICAL NOTE

EXAMINATION OF LPG AND PETROL FUELLED FORD ENGINES

BY

N. WEBB

INTRODUCTION

1. At the request of the Aeronautical Research Laboratories (ARL) and the Transport and Stores Branch of the Department of Administrative Services, (DAS) the Engineering Development Establishment (EDE) carried out an examination of five Ford 4.1 ℓ XB engines. The engines were installed in passenger sedans operated since new by DAS on normal passenger service. Two of the vehicles were operated solely on petrol and three solely on LPG. No initial examination of the engines had been made.

2. Identification of each vehicle's engine, fuel used and distance travelled is shown in Table 1:

TABLE 1 - DETAILS FOR EACH VEHICLE

SERIAL	ENGINE NO (a)	VEHICLE NO (b)	FUEL (c)	DISTANCE TRAVELLED (km) (d)
1	JG34P91171C	ZST-726	LPG	112674
2	JG34P90024C	ZST-727	LPG	104495
3	JG34P90399C	ZST-728	LPG	81346
4	JG34P90396C	ZST-781	Petrol	95021
5	JG34P91167C	ZST-782	Petrol	99899

3. This technical note published by EDE, is the last of three concerning the use of LPG in motor vehicles. Previous publications were:

a. EDE 3/78 - Examination of LPG and Petrol Fuelled Chrysler Engines.

b. EDE 28/79 - Laboratory Investigation of the Performance of a Holden Engine Operating on Liquified Petroleum Gas.

REQUIREMENT

4. To compare the condition of the engines that were converted to LPG operation with that of those operated on petrol.

PROCEDURE

5. A visual examination was made of the bores, sumps, camshafts, valve gear and combustion chambers of all engines and, additionally, of the pistons, connecting rods, crankshafts and bearings of engines Nos 90396C (petrol) and 90399C (LPG). Measurements also were made of the bores, rings, big end and main bearing clearances, valves and valve guides for the latter two engines.

OBSERVATIONS AND COMMENTS

Bore and Ring Measurements

6. A little less wear occurred in the bores and rings of the LPG engine measured, than in the petrol engine. From Tables 2 and 3 it is seen that between 0.016 and 0.026 mm taper was measured in the bores of the petrol engine and between 0.008 and 0.015 mm in the LPG engine. Ovality was similar for both engines. Top ring gaps varied between 0.47 and 0.78 mm for the petrol engine and between 0.50 and 0.60 mm for the LPG engine. In all bores of all five engines, honing marks were still visible although in both petrol engines, in parts of the bore, they were almost worn away. (Figs 1 and 2).

Bearing Clearances

7. Big-end and main bearing wear was low for both engines (Table 4). Big-end journal to bearing clearances were between 0.038 and 0.051 mm for the petrol engine and were all 0.051 mm for the LPG engine. Main bearing clearances were mostly 0.051 mm for the petrol engine and were all 0.063 mm for the LPG engine. The clearance measurements were carried out with deformable plastic clearance gauges giving a measurement resolution of 0.0065 mm. The measurements indicate that bearing wear was a little higher for the LPG engine.

8. Higher bearing wear in LPG engines is generally considered to result from the greater production of oxides of nitrogen due to the higher combustion temperatures. These result in the formation of acids which attack unplated copper/lead bearings. Whether this factor was significant in this case cannot be determined since although the main bearings were unplated copper/lead, the big-end bearings were plated copper/lead. In any case bearing wear in both measured engines was low.

Valve Guide Measurements

9. Bellmouthing at the top and bottom of the valve guides was greater for the LPG engine than for the petrol engine (Tables 5 and 6). For the petrol engine bellmouthing of the inlet guides varied between 0.005 and 0.025 mm and of the exhaust guides between 0.008 and 0.048 mm. For the LPG engine bellmouthing of the inlet guides varied between 0.027 and 0.046 mm and of the exhaust guides between 0.032 and 0.079 mm. Centre stem to centre guide clearances were similar for both engines (Table 7).

10. The greater bellmouthing of the LPG exhaust valve guides could perhaps be explained as due to higher side loads on the valve associated with incorrect seating due to greater valve and seat deterioration in the LPG engine. However the condition of the inlet valve faces and seats was similar for both engines, both having heavy pitting and little wear, hence the bellmouthing cannot be adequately explained.

Exhaust and Inlet Valves

11. There was heavy pitting of the exhaust valve faces in all LPG engines (Fig 3). Most faces also had a hard lacquer - like coating, probably arising from ash deposits resulting from burning of lubricating oil. Guttering had occurred in the coating of one of the valve faces in engine No 90024C and further exhaust valve guttering, and consequent burning, appeared imminent in this and the other LPG engines.

12. By contrast exhaust valve faces in the petrol engines were lightly or moderately pitted and had a soft ash coating with hard ash deposits in the pits.

13. Both LPG and petrol exhaust valve seats varied from lightly to heavily pitted, with the LPG seats being generally more heavily pitted. Many of the inlet valve faces and seats in both the petrol and LPG engines were also heavily pitted, however there was little wear apparent on the faces or seats of either of the exhaust or inlet valves for any of the engines.

14. There was moderate carbon build-up on the stem side of all inlet valve heads of both the petrol engines. For the LPG engines build-up varied from very light to heavy in engine Nos 90399C and 90024C and from very light to moderate for engine No 91171C (Fig 4). There was no evident pattern to the variation in carbon build-up between cylinders of the LPG engines nor could it be correlated with valve guide wear and consequent oil flow down the valve stem.

Pistons and Cylinders

15. Carbon deposits around the periphery of the piston crowns, on the bores above top ring travel and on the squish area of the combustion chambers were heavier in the three LPG engines than in the two petrol engines (Figs 5 to 8). In these areas the deposits varied from moderate to heavy in the LPG engines and from light to moderate in the petrol engines. The central area of the piston crowns and the main area of the combustion chambers of all engines had light deposits. An associated effect to the heavier peripheral carbon deposits in the LPG engines was light scuffing on the thrust side of the top ring lands of most of the LPG pistons examined. This is caused by hard carbon or ash deposits lodging between the land and bore. There was no scuffing of petrol engine top ring lands for those pistons examined. The light scuffing of the top ring lands in LPG engines would be unlikely to develop into a problem.

16. The probable cause of the carbon build up in the squish areas is the large surface to volume ratio in these areas resulting in oil on the upper cylinder walls being only partly burnt. The effect can be expected to be less in the petrol engines since dilution of the oil by the wet fuel would cause it to be more readily burnt. The build up would be expected to continue until the squish volume was filled or until a prior equilibrium state was reached as pieces of deposit broke away. The squish volume was in fact filled or almost filled in several of the LPG engine cylinders.

17. Although pre-ignition could be more of a problem in the LPG engines due to higher combustion chamber temperatures, the LPG engines would otherwise be expected to be less adversely affected by deposit build-up. The effectively higher compression ratio due to the deposits would be unlikely to cause detonation because of LPG's high octane number.

Cams and Lifters

18. The peak of all inlet and exhaust cam lobes were pitted on the petrol engines (Figs 9 to 11). In the LPG engines pitting occurred on some inlet lobes only. In all engines pitting tended to be worse towards the front end of the camshaft indicating a possible inadequate oil supply to this region. Most valve lifter faces in the petrol engines were also pitted. Most lifter faces on LPG engines No 90399C were slightly pitted, one only on No 901171C and none on No 90024C. The more extensive pitting of the cam lobes and lifters in the petrol engines may have been due to depletion of anti-oxidant additive by acids produced during the formation of lacquer (see para 21). In most oil formulations the anti-oxidants are also the extreme pressure anti-wear additives.

Rocker Shafts and Rockers

19. Some rocker journals of the rocker shafts of all engines were badly scored. Seven to nine were at least lightly scored on the LPG engines and there were five on each of the petrol engines. The respective corresponding rockers were also scored. All five rocker shafts and the affected rockers would need replacing. There was no apparent pattern associated with which rockers and journals were worn. A generally inadequate oil supply to the rockers is indicated.

Manifolds

20. The inlet manifold ducts of both petrol engines were coated with carbon at the cylinder ends. The coatings were generally about 1 mm thick, being slightly heavier in engine No 91167C. The LPG inlet duct surfaces were mostly free of carbon except for some isolated spotting particularly around the rim of the inlet ports. However in all LPG engines Nos 1 and 6 inlet ducts were heavily lacquered at the cylinder end. Additionally No 4 inlet duct of engine No 90399C and the remaining four inlet ducts of engines No 91171C were lightly lacquered.

21. Examination of the hoses from the PCV valve to the inlet manifold of all engines showed their inside surfaces to be wet with oil indicating that oil was being sucked past the valve. In the petrol engines the wet fuel would have thinned the oil, aiding decomposition to carbon. In the LPG engines the heavy unthineed oil has tended to be flung to the ends of the manifold and onto the surface of Nos 1 and 6 inlet ducts where it has oxidised and polymerised to form lacquer.

Cleanliness

22. The LPG engines were much cleaner than the petrol engines with virtually no lacquer and only a smear of sludge on the bottoms of each of the sumps. (Figs 12 to 14). There was extensive lacquer on the petrol engine pistons, and on all oil wetted parts of these engines. There was also a 1 to 2 mm thick layer of sludge covering the bottoms of the sumps and the timing cases of the petrol engines. They also had sludge deposits in their oil scraper ring grooves, in some cases partially blocking the slots.

DISCUSSION

23. The most significant difference between the condition of the LPG and petrol engines was the extent of the pitting of the exhaust valve faces. Although all engines required valve re-facing and re-seating, each of the LPG engines were close to burning out one or more exhaust valves with resultant loss in engine performance.

24. The carbon build-up in the combustion chambers of the LPG engines is a potential problem area in this model engine, due to the possibility of pre-ignition and piston scuffing.

25. Wear, generally, was lower in the LPG engine measured than in the petrol engine and all LPG engines were much cleaner.

RECOMMENDATIONS

26. It is recommended that trials be carried out on each and every engine type and vehicle application that might be considered for conversion to LPG operation. This recommendation is the same as that made in EDE Technical Note No 3/78 "Examination of LPG and Petrol Fuelled Chrysler Engines", wherein serious exhaust valve seat erosion was reported. Although adverse effects of LPG operation were not as serious in this engine and although at 100 000 km the vehicles had exceeded the normal disposal life of 50 000 km, the potential for serious problems has still been illustrated.

27. It is also recommended that, where possible, vehicles with factory modified engines and factory installed fuel systems be purchased for any future evaluations. In these cases higher volume purchases would be justified.

TABLE 2 - BORE AND RING MEASUREMENTS - ENGINE NO JG34P90396C (PETROL)

Cyl No	Diameter - mm					Taper	Top Ring Gap	Ovality C-E
	Pos A	Pos B	Pos C	Pos D	Pos E	mm	mm	mm
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1	93.541	93.553	93.564	93.528	93.508	0.023	0.73	0.056
2	93.533	93.540	93.549	93.493	93.486	0.016	0.47	0.063
3	93.543	93.555	93.567	93.525	93.523	0.024	0.72	0.044
4	93.533	93.540	93.551	93.503	93.494	0.018	0.57	0.057
5	93.526	93.547	93.552	93.504	93.506	0.026	0.55	0.046
6	93.564	93.578	93.584	93.528	93.530	0.020	0.78	0.054

TABLE 3 - BORE AND RING MEASUREMENTS - ENGINE NO JG34P90399C (LPG)

Cyl No	Diameter - mm					Taper	Top Ring Gap	Ovality C-E
	Pos A	Pos B	Pos C	Pos D	Pos E	mm	mm	mm
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
1	93.546	93.552	93.561	93.517	93.519	0.015	0.60	0.042
2	93.542	93.548	93.557	93.498	93.507	0.015	0.55	0.050
3	93.553	93.556	93.561	93.502	93.514	0.008	0.55	0.047
4	93.541	93.546	93.550	93.497	93.506	0.009	0.52	0.044
5	93.543	93.547	93.551	93.494	93.498	0.008	0.50	0.053
6	93.542	93.550	93.557	93.492	93.492	0.015	0,52	0.065

Notes: Position A - 25 mm down from top of bore at 90^{o} to crankshaft
Position B - 50 mm down from top of bore at 90^{o} to crankshaft
Position C - 100 mm down from top of bore at 90^{o} to crankshaft
Position D - 25 mm down from top of bore parallel to crankshaft
Position E - 100 mm down from top of bore parallel to crankshaft

TABLE 4 - BEARING CLEARANCES

Bearing No (from front)	Main		Big End	
	Petrol mm	LPG mm	Petrol mm	LPG mm
(a)	(b)	(c)	(d)	(e)
1	0.051	0.063	0.038	0.051
2	0.051	0.063	0.044	0.051
3	0.051	0.063	0.051	0.051
4	0.051	0.063	0.044	0.051
5	0.051	0.063	0.051	0.051
6	0.051	0.063	0.038	0.051
7	0.063	0.063		

TABLE 5 - VALVE GUIDE DIAMETERS AT RIGHT ANGLES TO ROCKER SHAFT (PETROL)

Cylinder / Valve Guide (a)	1 mm (b)	2 mm (c)	3 mm (d)	4 mm (e)	5 mm (f)	6 mm (g)
Inlet Top	8.748	8.751	8.761	8.746	8.758	8.747
Inlet Centre	8.743	8.744	8.741	8.740	8.746	8.739
Inlet Bottom	8.757	8.764	8.752	8.755	8.763	8.764
Exh Top	8.748	8.750	8.751	8.749	8.760	8.760
Exh Centre	8.737	8.732	8.740	8.741	8.741	8.741
Exh Bottom	8.765	8.763	8.788	8.786	8.769	8.774

TABLE 6 - VALVE GUIDE DIAMETERS AT RIGHT ANGLES TO ROCKET SHAFT (LPG)

Cylinder / Valve Guide (a)	1 mm (b)	2 mm (c)	3 mm (d)	4 mm (e)	5 mm (f)	6 mm (g)
Inlet Top	8.787	8.789	8.776	8.784	8.790	8.757
Inlet Centre	8.746	8.743	8.741	8.740	8.746	8.744
Inlet Bottom	8.777	8.783	8.768	8.780	8.778	8.778
Exh Top	8.783	8.772	8.821	8.781	8.780	8.775
Exh Centre	8.742	8.740	8.744	8.743	8.747	8.743
Exh Bottom	8.815	8.798	8.813	8.781	8.817	8.806

TABLE 7 - VALVE STEM TO GUIDE CLEARANCES

CENTRE STEM TO CENTRE GUIDE

AT RIGHT ANGLES TO ROCKER SHAFT

Cylinder / Valve Stem (a)	1 mm (b)	2 mm (c)	3 mm (d)	4 mm (e)	5 mm (f)	6 mm (g)
Petrol Inlet	0.075	0.079	0.082	0.070	0.085	0.074
Petrol Exh	0.087	0.092	0.080	0.095	0.092	0.099
LPG Inlet	0.081	0.074	0.072	0.076	0.085	0.080
LPG Exh	0.088	0.079	0.080	0.098	0.087	0.088

FIG 1 - LPG ENGINE NO JG34P91174C (7120-A0)

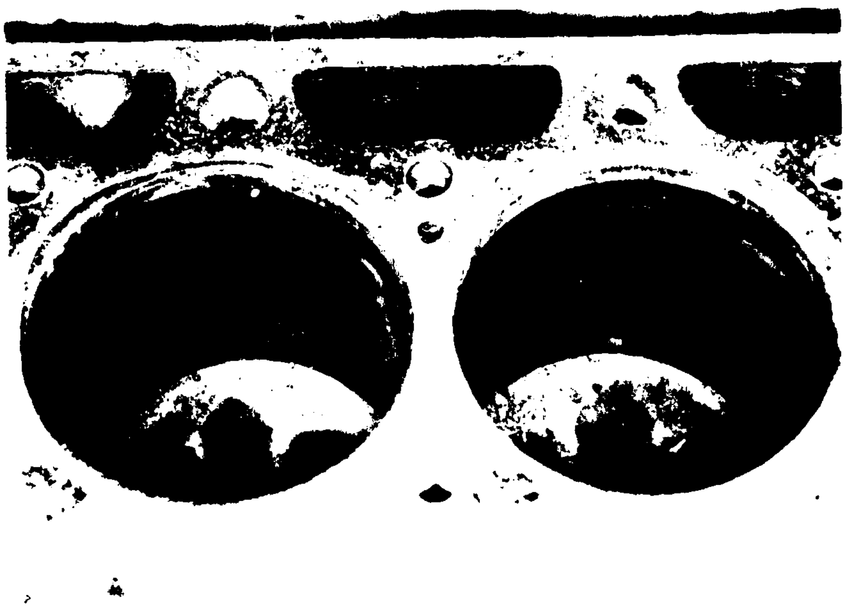

FIG 2 - PETROL ENGINE NO JG34P90396C (7120-A1)

NUMBER 3 AND 4 BORES FOR BOTH ENGINES
SHOWING HONING MARKS

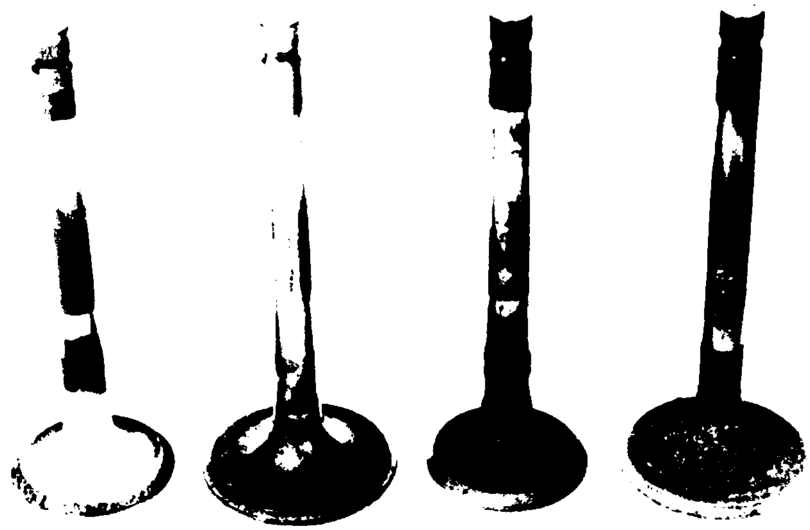

FIG 3 - VALVE FACES (TYPICAL) NO 4 CYLINDERS (7120-BG)
ENGINE NOS JG34P90399C (LPG) JG34P90396C
(PETROL) L TO R LPG EXHAUST AND INLET
PETROL EXHAUST AND INLET

FIG 4 - CARBON BUILD-UP ON INLET VALVES (7120-AU)
ENGINE NOS JG34P90024C (LPG) JG34P91167
(PETROL) L TO R LPG NOS 1,3,6, PETROL
NO 3 (TYPICAL)

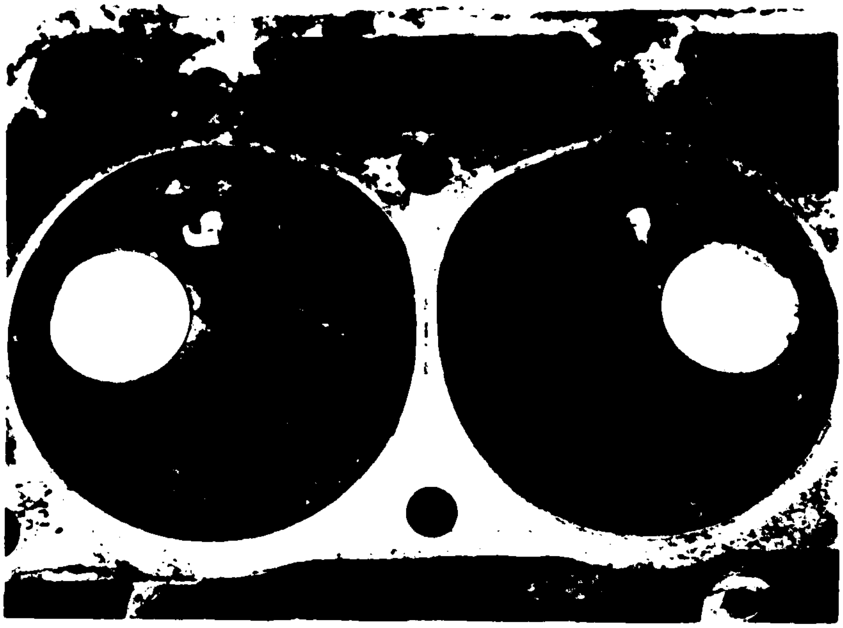

FIG 5 - COMBUSTION CHAMBERS (7120-J)

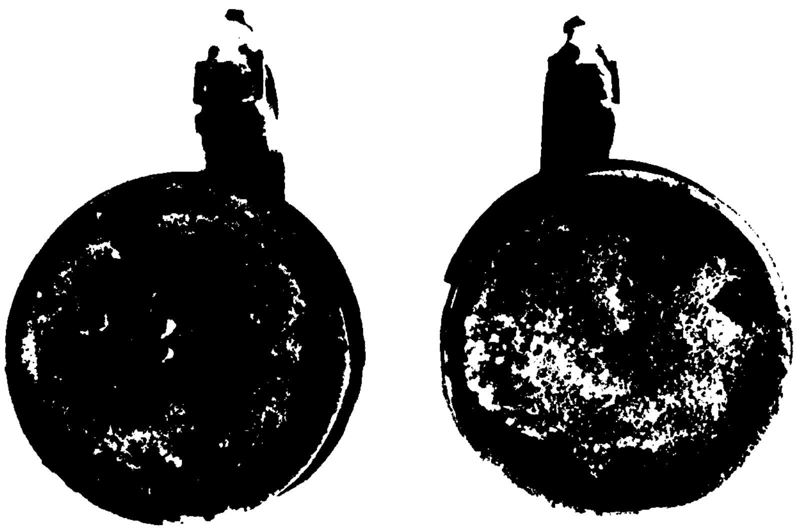

FIG 6 - PISTON CROWNS (7120-AY)

DEPOSIT BUILD UP IN COMBUSTION CHAMBERS
AND ON PISTON CROWNS - ENGINE NO JG34P90399C
(LPG)

LEFT - NO 1 RIGHT - NO 2

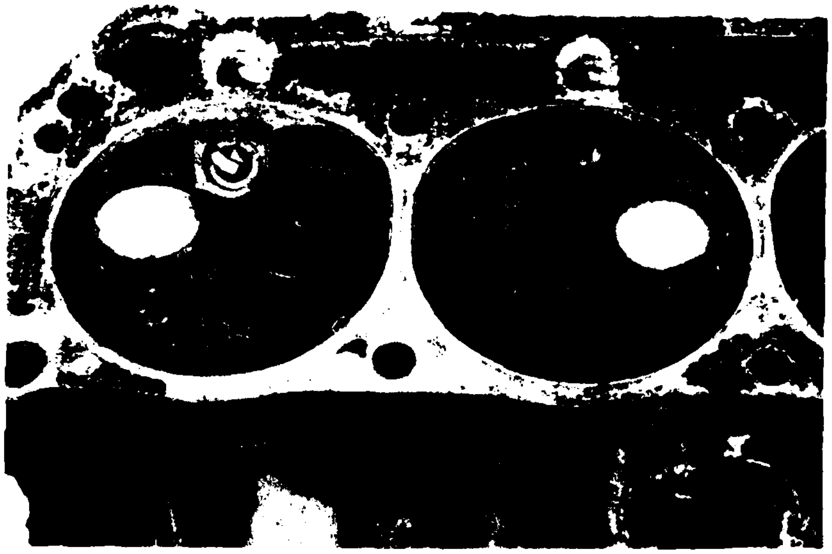

FIG 7 - COMBUSTION CHAMBERS (7120-T)

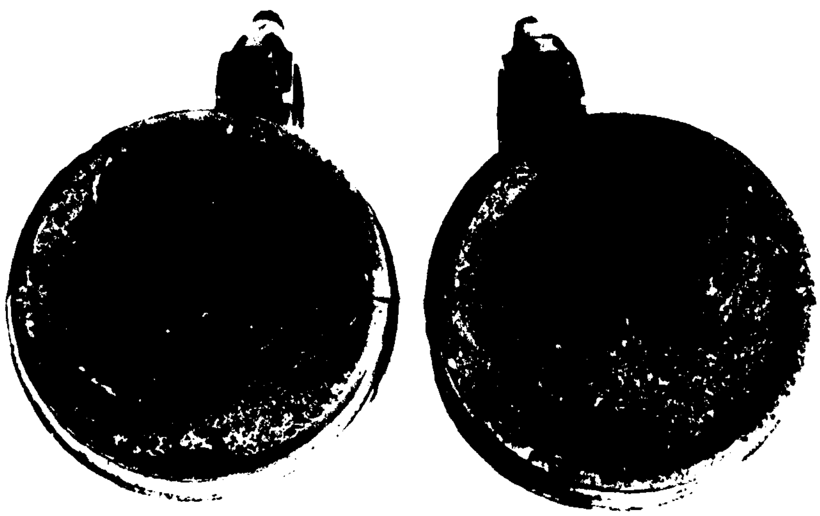

FIG 8 - PISTON CROWNS (7120-AV)

DEPOSIT BUILD UP IN COMBUSTION CHAMBERS
AND ON PISTON CROWNS - ENGINE NO JG34P90396C
(PETROL)

LEFT - NO 1 RIGHT - NO 2

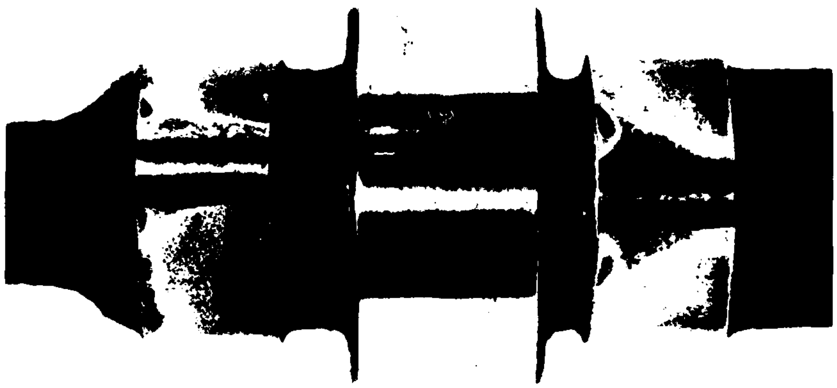

FIG 9 - PITTING ON CAM LOBES (7120-BU)
ENGINE NO JG34P90396C (PETROL)
L - NO 2 INLET R - NO 3 EXHAUST

FIG 10 - PITTING ON VALVE LIFTER FACES (7165-A)
ENGINE NO JG34P90396C (PETROL)
L TO R NO 5 INLET, NO 5 EXHAUST,
NO 1 INLET, NO 1 EXHAUST

FIG 11 - PITTING ON CAM LOBE - NO 2 EXHAUST (7120-BR)
ENGINE NO JG34P91171C (LPG)

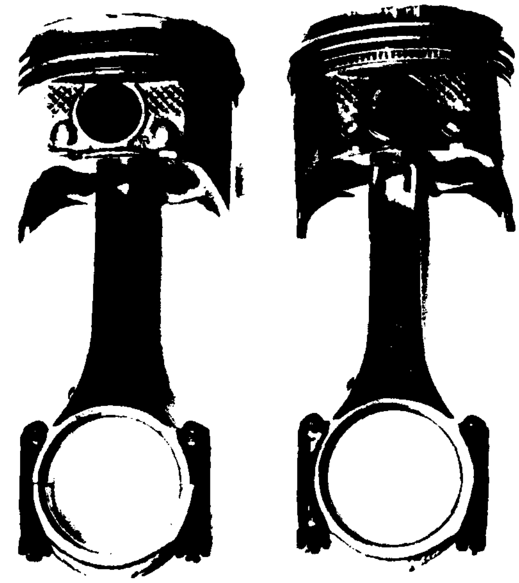

FIG 12 - TYPICAL ENGINE PISTONS SHOWING LACQUER (7120-BE)
L - LPG R -PETROL

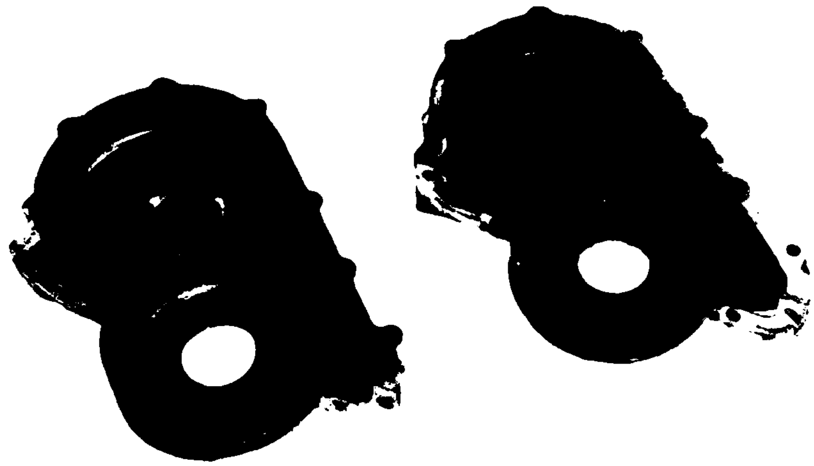

FIG 13 - TYPICAL TIMING CASES (7165-I)

FIG 14 - TYPICAL SUMPS (7120-BC)

TYPICAL ENGINE TIMING CASES AND
SUMPS SHOWING SLUDGE AND LACQUER

L - LPG R - PETROL

Department of Defence

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16. Abstract

This document covers the examination and comparison of the condition of FORD 4.1 ℓ XB engines operated for approximately 100 000 km on LPG and petrol.

The LPG engines exhibited less wear and were much cleaner than the petrol engines. However, the LPG exhaust valve faces were badly pitted and combustion chamber carbon build up was excessive.

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